Assessment of the Benefits and Costs Associated with the Adoption of the Recommended Fire Safety Practices for Materials Selection

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16. Abstract

This report presents the results of an assessment of the benefits and costs associated with the adoption of Recommended Fire Safety Practices for Materials Selection for rapid rail transit and light rail transit vehicles. The potential benefits to accrue are identified and discussed. Changes in vehicle construction costs are calculated using several methods of analysis. The Recommended Fire Safety Practices and respective test conditions are presented in Appendix A.

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PREFACE

The national urban mass transit system moves millions of passengers daily and thus is a key factor in meeting the transportation needs of this country. Service is expanding and ridership is growing. Increasingly strong, lightweight, modern materials are being introduced in the construction of mass transit vehicles. However, some of these materials may significantly increase the fire hazard of these vehicles to riders. The Urban Mass Transportation Administration (UMTA) is developing Recommendations for Fire Safety Practices for these materials in their application to rapid rail transit and light rail transit vehicles. This report examines the impact of these Recommended Fire Safety Practices in terms of the benefits to accrue from their adoption and the potential effects on vehicle costs.

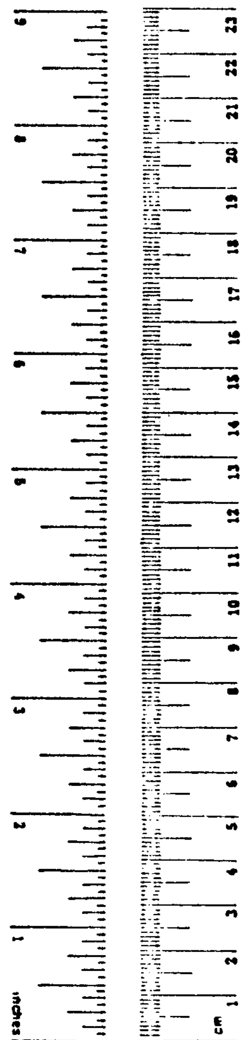
The authors wish to thank William J. Rhine and Robert I. Haught of UMTA for their valuable guidance and comments on this evaluation. Important contributions were made by the following individuals: Herbert L. Bogen, Stephanie H. Markos, and Ira M. Dinkes, Raytheon Service Company, who prepared Section 4 and Appendix B; and Irving Litant and Alfred E. Barrington, Transportation Systems Center, who prepared Appendix A and provided comments on the final draft.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

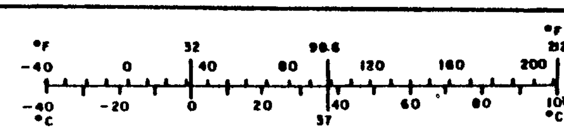
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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LIST OF ABBREVIATIONS

BART	Bay Area Rapid Transit
LRT	Light Rail Transit
LRV	Light Rail Vehicle
PCC	President's Conference Commission cars
PVC	Polyvinyl chloride/acrylic
RRT	Rapid Rail Transit
TA	Transit Authority
TSC	Transportation Systems Center
UMTA	Urban Mass Transportation Administration

1. INTRODUCTION

The threat of fire in rapid rail transit (RRT) and light rail transit (LRT) is of major concern considering the large number of passengers carried and the high capital investment involved. It is expected that ever larger numbers of passengers will be transported by mass transportation and that increasingly greater demands will be placed on mass transportation vehicles. Consequently, it is important that fire safety not be overlooked by mass transit properties or by manufacturers of mass transit vehicles.

A recent study[1] sponsored by the Urban Mass Transportation Administration (UMTA) revealed that the majority of transit vehicle fire and smoke incidents are minor in nature and do not develop into more serious incidents. The study further stated that "the reported fire rate of occurrence of the six RRT properties surveyed during 1978, was 5.22 incidents per million vehicle miles." Presumably, many of these occurrences could have developed into life threatening events if not detected and dealt with in a timely manner. One accident in 1979 resulted in one death and many injuries and at least $6,500,000 in damages. The UMTA Rail Transit Safety Annual Report[2] indicates that between August 1975 and May 1978, RRT fire damage alone amounted to $1.8 million. The criteria for entering incidents in the UMTA report are $2300 in equipment damage or one worker-day injury. There is reason to believe that many incidents occur which meet these criteria but are not reported.

The available data on RRT and LRT vehicle fires do not allow a realistic prediction of the number of major fire incidents for any given year; however, when a major fire incident does occur, large numbers of people are exposed to fire threats and the resulting property damage is considerable. The following documented incidents illustrate these points:

- A loose equipment cover fell from beneath an RRT car in the Transbay Tube beneath San Francisco Bay on January

17, 1979. The fallen cover was knocked about by several following trains, and caused the third rail to become misaligned. This misaligned third rail caused the contact shoe of another train carrying 40 passengers to short, arc, and start a fire. With the train stopped, the tunnel filled with smoke as the fire grew involving materials within the vehicle's occupant compartment. Further events caused hundreds of people on a rescue train to be taken into the tunnel and exposed to the hazards of smoke and toxic gases from the burning materials. The final outcome of this accident included the death of a firefighter, injuries to 46 persons, and the closing of the Transbay Tube for three months for repairs.

- A trolley wire fell on a LRT car in subsurface operation in Boston on July 3, 1975. The ensuing fire destroyed the car. Four hundred passengers walked 50 yards through dense smoke resulting from burning car materials to escape from the tunnel. Thirty-nine firefighters were hospitalized for smoke inhalation.

These are only two illustrations of the fire threat presented by RRT and LRT vehicles. Reference 1 provides additional examples of the potential fire threat presented by rail transit vehicles and an insight into the role of vehicle materials in the ignition and propagation phases of fires.

Recent trends in the design and construction of rapid rail transit and light rail transit cars have resulted in the increased use of synthetic, non-metallic materials, such as polymers (plastics and elastomers) and other flammable materials, in many transit car component applications. These materials provide lighter component weight while maintaining necessary strength characteristics. In many instances, they are more attractive to transit riders and may also result in easier fabrication, installation, and maintenance operations.

In RRT and LRT cars these materials may be used in seat cushions, floor construction, floor coverings, wall and ceiling

panels, windows, ducting, lighting fixtures, gasketing, insulation, etc. These applications are of concern in fire safety engineering since they represent the major fire load in RRT and LRT cars. They are seen to be critically involved in the ignition and propagation phases as well as in smoke and toxic gas generation. The fire threat is especially serious in subsurface situations where difficulties in evacuation of personnel and problems in dispersal of smoke intensify the dangers. Furthermore, since use of these materials continues to increase, past fire experience may understate the consequences of their unrestricted application in RRT and LRT cars. This document presents an analysis of the costs and benefits associated with the adoption of Recommended Fire Safety Practices for Materials Selection contained in Appendix A. The cost estimates on which this analysis was conducted were obtained during the first quarter of the 1980 calendar year.

2. DEVELOPMENT OF RECOMMENDED FIRE SAFETY PRACTICES FOR MATERIALS SELECTION

In 1973, the Urban Mass Transportation Administration, as part of its mission of improving mass transportation, initiated an effort to evaluate and improve fire safety in transit vehicles. In 1974, "Guidelines for Flammability and Smoke Emission Specifications" of materials used in transit vehicles were developed by the Transportation Systems Center (TSC) for UMTA. Since that time these Guidelines have undergone periodic review and updating. At present, the Guidelines have generally been voluntarily accepted by the transit industry. This voluntary acceptance by the transit industry has minimized the cost impact of their adoption as recommendations. The recommendations contained in Appendix A are based on these Guidelines and will formalize them for use in future rail transit vehicle procurements and possible vehicle retrofit programs. The recommendations are based on performance of presently available materials.

3. ASSESSMENT OF BENEFITS

As noted in section 2, the Guidelines have generally been accepted by the transit industry. As a result of this voluntary acceptance, many of the benefits expected to accrue from the adoption of the Recommended Fire Safety Practices for Materials Selection have already been realized. In the same manner, some of the costs associated with their adoption have already been expended. This section is directed at identifying and assessing the benefits and costs associated with the implementation of these recommendations.

The basic objective of the recommendations is to minimize the fire threat in transit vehicles by providing for:

- Increased resistance to ignition
- Decreased flame spread rates
- Decreased smoke emission
- Increased time for egress.

The primary benefit that will accrue from the recommendations is the decrease in the fire risk associated with RRT and LRT operations. This risk reduction will manifest itself in the form of lives saved, injuries prevented, and a reduction in property damage or capital losses. Quantification of these primary benefits is very complex as it is difficult to assign an adequate dollar value to deaths and/or injuries. Furthermore, data on the dollar property losses from fire is extremely limited. Therefore, loss estimates available are not in a form which allows for a quantitative determination of how the recommendations would influence these losses. Secondary benefits to accrue from the adoption of these recommendations are also very difficult to quantify, but should include the reduction of service delays, reduction of system downtime, and the possible increase in the number of riders as the public perceives transit systems to be more fire safe. Additional secondary benefits associated with these recommendations are improved safety for fire fighting and rescue crews, possible de-

creases in materials maintenance costs and a reduction in costs associated with fewer fire calls. To date, RRT and LRT operations have resulted in a limited number of deaths and injuries. These deaths and injuries have occurred in major incidents which, although infrequent, will continue to occur and may, with the increased use of polymeric materials, become more frequent and severe. For this reason, the national transit ridership, approximately 1.5 million passengers in 1978, should not be exposed to unnecessary risk.

4. ASSESSMENT OF THE COSTS

4.1 BACKGROUND

Three basic factors must be considered in assessing the cost impact of the Recommended Fire Safety Practices for Materials Selection.

The first factor is that the materials chosen (e.g., plastic versus metal) depend on various component specifications. These transit property specifications are not standardized and can vary according to the particular performance requirements desired, e.g., weight, durability, etc., by the individual property. It is not the intent of this analysis to prescribe the use of particular materials. Rather, a comparison of costs for comparable types of materials which meet or fail to meet the criteria of the recommendations will be presented.

The second factor is that certain materials which have for many years been used in transit vehicles already meet the recommendations.

The third factor for consideration is that the majority of transit properties have followed, to a major extent, the Guidelines in ordering new cars and in replacing vehicle components, although the Guidelines have not been formally promulgated. Thus, some materials in use already comply with the recommendations, and substantial further costs due to the adoption of the recommendations should not therefore accrue. In addition, although the materials applications addressed by the recommendations do not represent an insignificant part of the cost of a car, it should be noted that the total cost of car body materials is estimated to contribute only 10 percent of the total car costs.[3]

4.2 COMPOSITION OF THE FLEET

The national fleet of rail transit cars consists of approximately 10,000 rapid rail cars and 800 light rail cars. All cars currently in operation or projected for delivery within the next

5 years are included in this total. This fleet total includes all rapid rail transit car types[4] owned by United States properties.

4.2.1 Rapid Rail

Since 1968, 3859 new cars have been delivered to or ordered by 12 transit properties. This figure represents 38 percent of the total current rapid rail fleet of approximately 10,000 cars. A little over one-third of these new cars can be attributed to completely new systems (i.e., Washington DC, Miami, etc.) with actual or projected operations occurring since 1969. Figure 4-1 illustrates the distribution of rapid rail cars according to operation by both older and newer transit systems. The high percentage of cars delivered to new systems as related to total car orders will decrease sharply after the completion of current orders. About 88 percent of the total current/projected fleet is operated by the older systems (systems in operation prior to 1969, i.e., New York, Chicago, etc.). Based on a 30-year car replacement cycle, these older systems can be expected to account for the majority of future new car orders.

4.2.2 Light Rail

Approximately 800 cars comprise the national fleet of light rail transit cars. About 25 percent of these cars have been delivered since 1975. The rest of the fleet consists of PCC (President's Conference Commission) cars, most of which are over 25 years old. Specifications for the replacement of approximately 200 of these cars have been written and contracts awarded. Other cars are being completely overhauled.

4.3 INTERIOR COMPONENT MATERIALS

Prior to the development of the Recommended Fire Safety Practices for Materials Selection, the use of fire retardant materials for some components was explicitly specified by various transit properties. However, the definition of "fire retardant" differed and tests used to indicate compliance varied and have occasionally

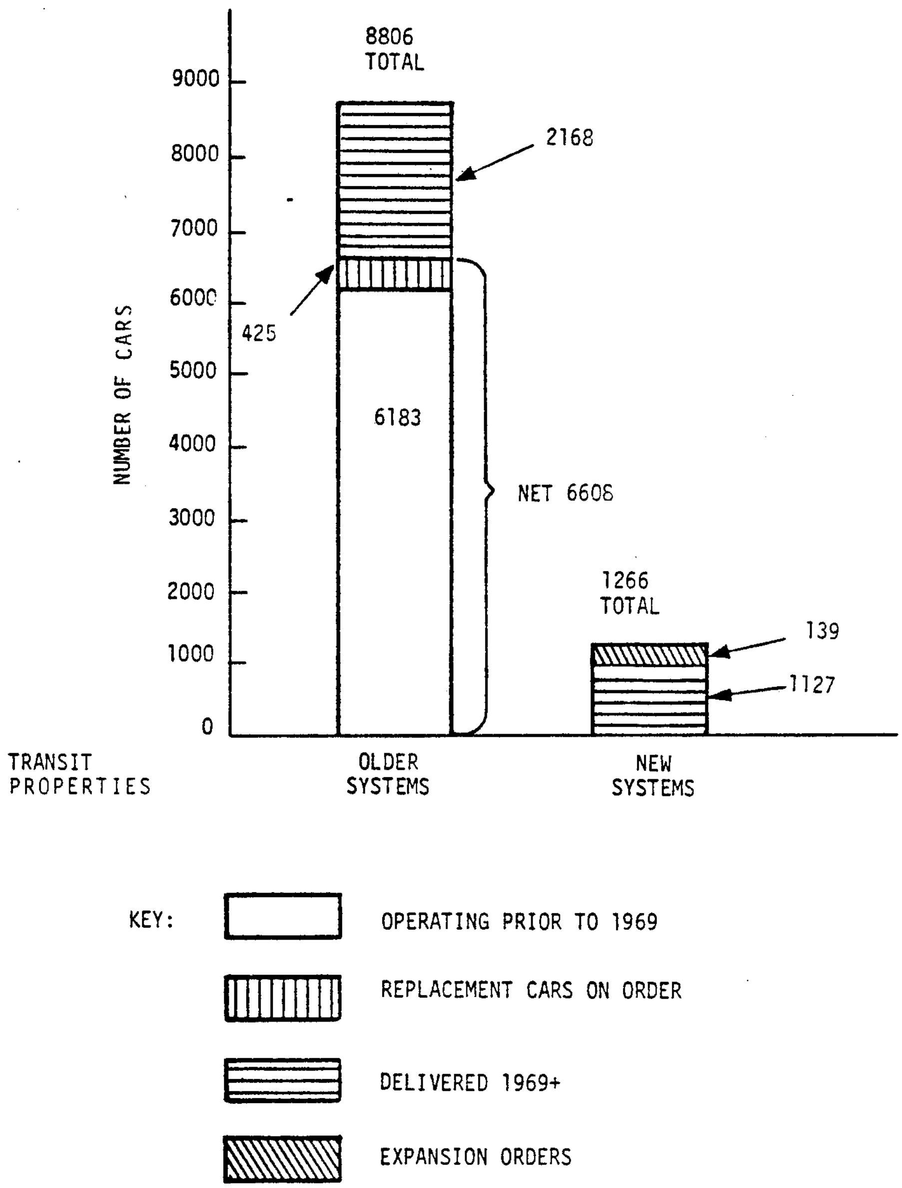


FIGURE 4-1. DISTRIBUTION OF RAPID RAIL CARS

been determined to be inadequate. This section is a summary of the types of materials used in the following components: seats, interior linings, floors, floor coverings, and windows. These components were chosen for this analysis because they comprise a large percentage of the car interior area and may represent the major fire load in the car. More detailed descriptions of the materials used in both RRT and LRT cars are contained in Appendix B.

4.3.1 Seats

The majority of new transit cars delivered or ordered during the last decade have been equipped with some kind of upholstered or padded seat (the exception is New York City). In an attempt to lessen costs associated with vandalism, many transit cars are now equipped with molded fiberglass seats which do not contain cushions.

4.3.2 Interior Linings

Wall panel materials that have been used include stainless steel sheets, balanced melamine, melamine plymetal, molded fiberglass or other plastic material including PVC/acrylics. Typical ceiling panels are made of sheet metal. Wainscotting, window masks, door pocket panels, and windscreens are included in the group "wall panels."

4.3.3 Floors

The floor panel typically consists of a thin metal sheet of aluminum or steel bonded to a plywood sheet. Other flooring material has included aluminum/polyurethane sandwich panels, plywood, and truss plates of steel and corrugated metal.

4.3.4 Floor Coverings

Vinyl and vinyl asbestos tile were once commonly used materials, but today the majority of cars utilize some form of rubber sheet or tile for the interior floor covering. Recently, some new systems have used wool carpeting with a foam rubber pad.

4.3.5 Windows

Windows and window glazing were not considered in the cost analysis because 97 percent of the cars in the RRT fleet contain laminated safety sheet glass which meets the recommended criteria. Alternative window types, such as scratch-resistant polycarbonate plastic or acrylic/glass sandwich windows, were not included since cost increases due to their usage are based on durability aspects and not fire safety considerations.

4.4 IDENTIFICATION AND ANALYSIS OF COSTS

By utilizing the fleet composition and the interior compartment materials data contained in Sections 4.2 and 4.3, it was possible to assess the costs associated with the adoption of the Recommended Fire Safety Practices for Material Selection. The cost analysis was directed at seats, wall and ceiling liners, window masks, floors, and floor coverings. Cost and weight data for certain interior components, e.g., lighting diffusers, thermal insulation, window and door seals, etc., could not be obtained.

This analysis was performed on the basis of cost. The cost of the materials which were used in rail transit cars (delivered between 1969 and 1979) was compared with the cost of the materials which meet the recommended criteria and are likely to be used in the near future. Since a large percentage of cars have either been delivered or ordered within the last ten years, 1969 was used as the cut-off year. It should be noted that often specific cost information for materials was unknown, difficult to quantify, or considered proprietary information. Transit properties do not require either a cost summary or a weight summary by component. Even if previous costs were available, the comparable costs in today's market are generally greater than the inflationary increase, due to the petrochemical nature of many components.

4.4.1 Cost Estimating Methodology

The cost analysis was performed by obtaining the weight or surface area of the particular component and multiplying it by the

1980 material unit cost. This was performed for the materials that are presently used, and for materials that meet the recommended criteria. After all costs in the analysis were found, the costs of Presently Used and Recommended materials were totalled and compared.

The cars used in this analysis included three types of RRT cars and one type of LRT car, all of which were delivered between 1969 and 1979. The transit car costs and material unit costs used were derived from a number of sources including published technical data summaries,[4] car bid specifications,[5] material and component suppliers, engineering consultants,[6] car builders,[7] and transit properties.

Three methods of analysis were employed:

1. Weighted fleet car method
2. Worst/Best case method
3. Individual car method

The detailed analysis performed with each method is contained in Appendix B.

The "weighted fleet car" (composite car) is a tool used to analyze a hypothetical "average" United States transit car. Basically, each type of car contributes its "weight" to the "average" fleet car; if car type 1 comprised 80 percent of the total fleet, it contributed 80 percent of the data concerning a particular component. The "weighted fleet car" used in the analysis is a composite of the three RRT cars mentioned above.

The "worst/best" case method compared the cost of a transit car containing materials which do not meet the recommended criteria to the cost of a car containing materials which do meet the recommendations. For example, the "worst" case car could contain polyurethane seat cushions and plywood floors, both of which are flammable. The "best" case car would contain materials which are less flammable and meet the criteria of the recommendations.

In the individual car analysis, estimated cost increases due to adoption of the recommendations were based on actual new car specifications used by three RRT properties and one LRT property.

4.4.2 Cost Analysis Results

This section presents a summary of the cost analysis. Detailed calculations and commentary are contained in Appendix B. The percentage increase in car acquisition costs for using Recommended materials, as calculated with the "weighted fleet car" method, was approximately 0.43 percent. The percentage increase in car cost in the "worst/best" case method was 0.30 percent, if the cushionless, molded fiberglass seats are considered since they are less expensive than the cushioned, polyurethane seats. Substitution in the analysis of the more expensive neoprene seat cushions for the cushionless molded fiberglass seats raised the cost increase to 0.65 percent in the "worst/best" case.

The individual car analysis showed variations in acquisition cost increases, ranging from 0.08 to just under 1 percent due to different specifications used. The largest increase in cost was due to the substitution of a more expensive grade of PVC/acrylic plastic (extensively used for interior linings) which emits less smoke.

In all methods used, the expected increase in car costs was <u>less than 1 percent</u>. All methods used show close agreement. Additionally, the sensitivity analysis, contained in Appendix B, indicates that varying component costs and car life will not have a major effect on the national economy. The economic impact of the adoption of the recommendations should be quite minimal. This minimal cost impact is attributed to the voluntary acceptance by the transit properties, of the the "Guidelines for Flammability and Smoke Emission Specifications."

5. CONCLUSIONS

Three methods of analysis and an examination of the sensitivity of the results clearly demonstrate that the adoption of the Recommended Fire Safety Practices for Materials Selection will not have a significant effect on transit car procurement costs.

The small increase in costs is largely due to the voluntary compliance of transit properties to the existing Guidelines and to the fact that total car body materials costs comprise only about 10 percent of the cost of the car.[3]

There are several ways to evaluate the economic impact of the recommendations. The cost analyses summary presented in section 4 estimated increases in costs per car ranging from \$565 to \$7245, compared to a "weighted car" cost of approximately \$700,000. In all cases, increases amount to less than 1 percent of the expected car cost.

Current property damage estimates indicate that the cost of fire and smoke incidents in transit systems is in excess of \$1,000,000 per year. Assuming that 360 new transit cars are purchased each year and the cost increase for materials that meet the recommendations is approximately \$300 per car (weighted fleet car cost increase), the annual cost of the recommendations will be \$1,080,000 per year. Cost increases are comparable to the above conservative fire damage estimates. Thus, it is seen that a considerable increase in passenger safety could be obtained at a negligible increase in car cost by adoption of the Recommended Fire Safety Practices for Materials Selection.

6. ADOPTION OF RECOMMENDED FIRE SAFETY PRACTICES

There are several distinct stages for which the Recommended Fire Safety Practices for Materials Selection could be considered for adoption:

- New car construction only
- Retrofit of the present fleet
- Replacement of car materials as they wear out.

These stages are discussed below, together with alternative courses of action which are supported by the data collected and included in this study.

6.1 NEW VEHICLE CONSTRUCTION

It is determined from the summary analysis that adoption of the recommendations is warranted since the cost impact is estimated to be minimal and the improvement in fire safety will be significant. The benefits to the public and the transit properties will be well worth the investment.

6.2 TOTAL RETROFIT OF THE EXISTING FLEET

In the total retrofit alternative, the fleet of vehicles would be completely stripped of all materials which do not meet the recommendations and replaced by materials which do meet the recommendations. This alternative does not appear warranted and is not advised, as the costs of labor would be prohibitive and service disruptions would be severe. Finally, if such a massive retrofit program was initiated, unsubstantiated public concern could be aroused regarding the safety of existing vehicles.

6.3 MATERIAL REPLACEMENT AT WEAR-OUT

Adoption of the recommendations should apply to materials purchased for replacement of worn-out components. These recommenda-

tions should be adopted because the cost impact is minimal (See section 4.4). When a particular car component needs replacement, (e.g., seat cushions), it should be replaced with a material that meets the recommended criteria. There will be no significant cost impact since the labor cost of replacement is required no matter what material is selected. Only in instances where the design or basic configuration of the component is to be changed will there be any significant cost impact. This impact would be determined by the local transit property requirements which may depend on reasons other than improved fire resistance.

REFERENCES

1. Hathaway, W.T., and A.L. Flores, "Identification of the Fire Threat in Urban Transit Vehicles," UMTA, U.S. Department of Transportation, Report No. UMTA-MA-06-0051-80-1/DOT-TSC-UMTA-80-1, (June 1980).

2. "Rail Transit Safety, 1978 Annual Report," prepared by U.S. Department of Transportation, Research and Special Programs Administration, Transportation Systems Center, Cambridge MA, for UMTA, Office of Technology Development and Deployment, Washington DC.

3. "Cost Savings Potential of Modifications to The Standard Light Rail Vehicle Specifications," UMTA-MA-06-0025-79-11, N.D. Lea & Associates, (February 1979).

4. Roster of North American Rapid Transit Cars, 1945-76, UMTA-DC-06-0121-77-1. American Public Transit Association (January 1977).

5. Car bid specifications library maintained by Transit Systems Branch, Urban Systems Division, TSC.

6. Conversations with Charles P. Elms, N.D. Lea & Associates and Ray Cavenaugh, L.T. Klauder & Associates.

7. Material and weight data received from William Walker, Pullman Standard and William Dickhart, Budd Company.

APPENDIX A

RECOMMENDED FIRE SAFETY PRACTICES FOR MATERIALS SELECTION FOR RAPID RAIL AND LIGHT RAIL TRANSIT VEHICLES

1. APPLICATION

These recommendations provide fire performance criteria for five basic categories of material applications: Seating, wall and ceiling panels, flooring, thermal and acoustical insulation, and miscellaneous applications.

The fire performance criteria supersede those contained in drawings, specifications, and other related procurement documents.

Although the development of limits for toxic products of combustion is of major concern, the information necessary for the development of toxicity recommendations is not available at this time.

These criteria are determined largely by the performance of presently available materials.

2. REFERENCED DOCUMENTS

2.1 ISSUES OF DOCUMENTS

The following documents as issued or in effect on the date of invitation for bids or request for proposal are to be employed in the evaluation of the materials to the extent specified herein.

2.2 REFERENCED FIRE STANDARDS

<u>Governmental</u>

FED-STD-191A-Textile Test Methods 5830,
Leaching Resistance of Cloth

Federal Aviation Administration
Vertical Burn Test - FAR-25.853

<u>Non-Governmental</u>

American Society for Testing and Materials (ASTM):
- C-542 - Specification for Gaskets
- D-3675 - Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source
- E-119-Fire Tests of Building Construction and Materials
- E-162 - Surface Flammability of Materials Using a Radiant Heat Energy Source

National Fire Protection Association (NFPA):
- NFPA - 253 - Flooring Radiant Panel Test
- NFPA - 258 - Smoke Generated by Solid Materials

American Association of Textile Chemists and Colorists
- AATCC - 86

3. MATERIALS RECOMMENDATIONS

3.1 MATERIALS

It is recommended that the materials used in rapid rail and light rail transit vehicles be tested according to the test procedures set forth in Table A-1 and meet the performance criteria set forth in Table A-1.

TABLE A-1. MATERIALS RECOMMENDATIONS

Category	Function of Material	Test Procedure	Performance Criteria
Seating	Cushion[1;2;5]	ASTM D-3675	$I_s \leq 25$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Frame[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Shroud[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Upholstery[1;2;3;5]	FAR 25.853	Flame Time $\leq$10 sec; burn length $\leq$6 inch
		NFPA 258	$D_s(4.0) \leq 250$ coated $D_s(4.0) \leq 100$ uncoated
Panels	Wall[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Ceiling[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Partition[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Windscreen[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	HVAC Ducting[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(4.0) \leq 100$
	Window[4;5]	ASTM E-162	$I_s \leq 100$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Light Diffuser[5]	ASTM E-162	$I_s \leq 100$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
Flooring	Structural	ASTM E-119	Pass
	Covering	NFPA 253	C.R.F. $\geq 0.5 w/cm^2$
Insulation	Thermal[1;2;5]	ASTM E-162	$I_s \leq 25$
		NFPA 258	$D_s(4.0) \leq 100$
	Acoustic[1;2;5]	ASTM E-162	$I_s \leq 25$
		NFPA 258	$D_s(4.0) \leq 100$
	Elastomers[1]	ASTM C-542	Pass
Miscellaneous	Exterior Shell[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$
	Component Box covers[1;5]	ASTM E-162	$I_s \leq 35$
		NFPA 258	$D_s(1.5) \leq 100$; $D_s(4.0) \leq 200$

TABLE A-1. MATERIALS RECOMMENDATIONS - (Cont.)

NOTES:

1. Materials tested for surface flammability shall not exhibit any flaming running, or flaming dripping.
2. The surface flammability and smoke characteristics shall be demonstrated to be permanent by washing, if appropriate, according to Federal Test Method 191A method 5830.
3. The surface flammability and smoke characteristics shall be demonstrated to be permanent by dry-cleaning, if appropriate, according to AATCC-86.
4. For double window glazing, the interior glazing shall meet the materials criteria specified herein.
5. Maximum test limits for smoke emission in accordance with NFPA-258 apply in either the flaming or nonflaming modes, whichever is greater.

3.2 DEFINITION OF TERMS

The terms cited are defined as follows:

(a) The term "critical radiant flux" (CRF) is the level of radiant heat energy incident on the floor covering system at the most distant flameout point. It is reported as watts/cm^2. Its method of determination is covered in NFPA 253.

(b) The term "flame spread index" (I_s) refers to a factor derived from the rate of progress of the flame front (ignition properties) and another relating to the rate of heat liberated by the material under test, which are combined to provide the I_s. Its method of calculation is contained in ASTM E-162.

(c) The term "specific optical density" (D_s) is a measure characteristic of the concentration of smoke emitted by the material under test and is related to the time from the start of the test. Its method of determination is contained in NFPA Standard No. 258. Specific optical density is specified

in minutes (e.g., D_s (1.5) $\leq$ 100 is a specific optical density of 100 or less at 1.5 minutes into the test.)

(d) The term "surface flammability" means the rate at which flames will travel along surfaces and is dependent on physical and thermal characteristics of the material, as well as other factors.

(e) The term "rapid rail" means a subway-type transit vehicle railway operated on exclusive private rights-of-way with high-level platform stations.

(f) The term "light rail" means a streetcar-type transit vehicle railway operated on city streets, semiprivate rights-of-way, or exclusive private rights-of-way.

3.3 ADDITIONAL TEST PROVISIONS

Additional test provisions concerning upholstery, structural flooring, floor covering, and thermal and acoustic insulation materials are as follows:

(1) Upholstery materials of the same lot shall be tested for vertical flame resistance, in accordance with FAR-25.853, with a minimum of five specimens from each of the warp and fill directions and their results averaged (arithmetic mean).

(2) Structural flooring assemblies must meet the performance criteria in Table A-1 during a nominal test period or minimum test period of 15 minutes, whichever is greater. The nominal test period will be twice the maximum expected period of time, under normal circumstances, for a vehicle to come to a complete, safe stop from maximum speed, plus the time necessary to evacuate all passengers from a vehicle to a safe area. Only one specimen need be tested.

(3) Carpeting shall be tested in accordance with NFPA-253 with its padding, if the padding is used in actual installations.

(4) Thermal and acoustic insulation materials shall be tested for surface flammability, as specified in Table A-1, using wire mesh screening (as per section 5.92 or ASTM E-162).

(5) With the exception of structural flooring and upholstery, unless otherwise specified, no less than three specimens should be tested on material of the same lot, with results averaged (arithmetic mean) to determine whether the performance criteria are satisfied.

APPENDIX B

DETAILED ASSESSMENT OF THE COSTS

1. COMPOSITION OF THE FLEET

The national fleet of rail transit vehicles consists of approximately 10,000 rapid rail cars and 800 light rail cars. All cars currently in operation or to be delivered within the next 5 years are included in this total.

Detailed information describing the composition of the national fleet of vehicles is contained in section 4.2.

2. INTERIOR COMPONENT MATERIALS

This section reviews in detail the types of materials used in the following components: seats, interior linings, floors, floor coverings, and windows. The data are derived from a variety of sources, including published technical data summaries,[1] car bid specifications,[2] engineering consultants,[3] material and component suppliers, car builders,[4] and transit properties.

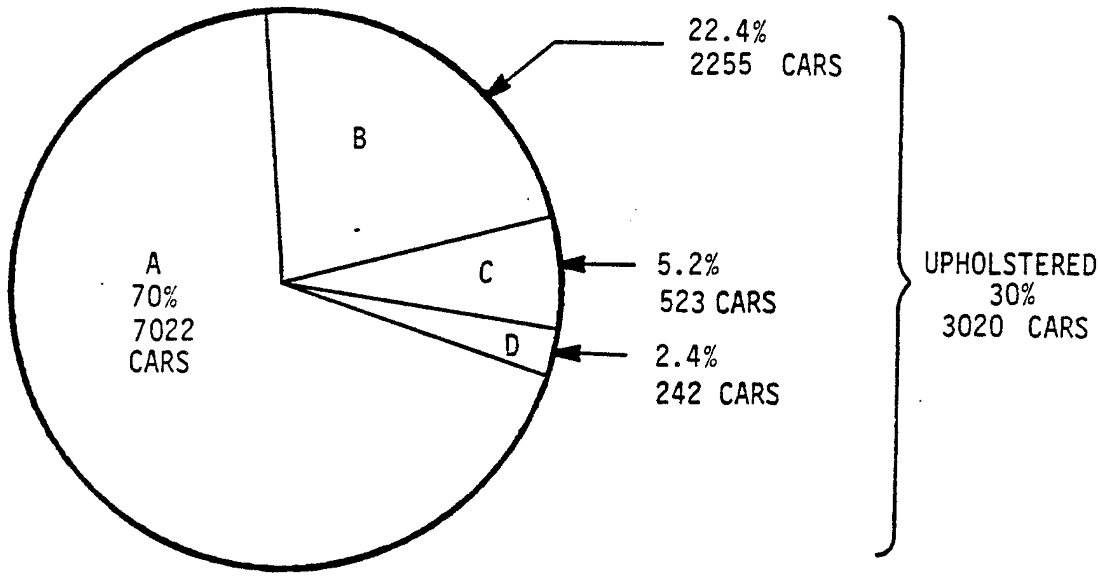
Past transit property requirements for these materials have included durability, ease of maintenance, resistance to vandalism, weight, physical and mechanical properties, (i.e., heat distortion resistance, etc.) and cost. During the last 10 years, specifications emphasizing passenger comfort, visual appeal, and noise reduction have been included.

2.1 RAPID RAIL

2.1.1 Seats

Rapid rail transit vehicles are equipped with various types of seats using different materials. Figure B-1 illustrates the distribution of seats in the rapid rail fleet by seat type.

The majority of new transit cars delivered or ordered during the last decade have been equipped with upholstered or padded seats. New systems, in particular, have specified this type of seat in order to offer passengers a higher level of ride comfort. Approximately 30 percent of the current/projected fleet is equipped with this type of seat. At one time, the cushion material in the majority of cars with upholstered or padded seats consisted of polyurethane. This material is relatively inexpensive, easy to form, and is commonly used in automobile, bus, and aircraft seat cushions. Once ignited, however, it quickly promotes flame spread and emits large quantities of dense smoke and toxic fumes. In general, transit fire experience has demonstrated the hazards presented by this material (particularly during tunnel fires).



A. MOLDED PLASTIC FIBERGLASS
B. NEOPRENE CUSHION
C. POLYURETHANE/LATEX CUSHION
D. OTHER CUSHION

TOTAL: 10,042 CARS

FIGURE B-1. RAPID RAIL TYPES OF SEAT MATERIALS

For these reasons, polyurethane has not been used for seat cushioning material in rapid transit cars ordered or delivered after 1974. Neoprene, a self-extinguishing elastomer which is significantly less hazardous, has become the preferred material for cushions.

Certain transit properties, such as Bay Area Rapid Transit (BART), have initiated seat replacement programs for vehicles containing polyurethane or latex seat cushions. In addition, older cars containing polyurethane cushions will be replaced by new cars. As a result, the current/projected number of cars containing polyurethane or latex seat cushions has declined by about 84 percent from the number of cars originally so equipped. Figure B-1 shows that only about 5 percent of the cars in the total fleet will then contain polyurethane seat cushions.

In an attempt to lessen costs resulting from vandalism, many transit cars are equipped with molded fiberglass seats. These seats do not contain cushions vulnerable to vandalism. About 70 percent of the total current/projected cars in the national fleet are equipped with this type of seat.

2.1.2 Interior Linings

2.1.2.1 Ceiling Liners - The majority of cars contain interior metal ceilings. Metal ceiling panels can consist of porcelainized, vinyl-covered or melamine-faced aluminum. In addition, a "sandwich" consisting of particle board bonded to melamine-aluminum (a plymetal) has been used. Various plastics, including balanced melamine, PVC/acrylic and fiberglass have also been used as ceiling liners.

2.1.2.2 Wall Linings - a. Wainscotting is the wall area located between the bottom of the window and the floor. (The area immediately around the window is defined as a window mask and is described separately.) Typically, wainscotting is made of stainless steel, balanced melamine, or a "sandwich" melamine plymetal

panel. A factor influencing the material used is whether the wainscotting is integrated with the window mask. Integrated wainscotting consists of a PVC/acrylic or whatever material comprises the window mask. In some cars, the arrangement of seats longitudinally against the side of the car eliminates the necessity of the wainscotting.

b. Window masks are defined as the interior lining panels bordering the windows. Typically, the panels are between 20 and 40 square feet; the window fits into a "cut-out" area. The material most commonly used is a fire retardant molded polyester fiberglass material. Other materials used have included PVC/acrylic and polycarbonate fiberglass.

c. Door pocket panels are located on either side of the doors. These usually consist of plymetal which is melamine/aluminum sheets bonded to particle board or plywood.

d. Windscreens are panels located at right angles to the passenger loading doors. They are intended to diminish the drafts of air entering the car. Typical materials used are glass, aluminum, and melamine plymetal sheets.

2.1.3 Floors

The floor panel usually consists of a plywood sheet bonded to a thin metal sheet of aluminum or steel, on one or both sides. Plymetals comprise the majority of floor panels used. Other flooring materials have included aluminum/polyurethane sandwich panels, plywood, and truss plates of steel and corrugated metal.

A subflooring, if used, consists of a separate, flat or corrugated, metal sheet. Insulation may be located in the air space between the plymetal panels and the subflooring.

2.1.4 Floor Coverings

Vinyl and vinyl asbestos tile were once commonly used materials, but today the majority of vehicles utilize some form of hard rubber sheet or tile for the interior floor covering.

Recently some new systems have used wool carpeting with a foam rubber pad.

2.1.5 Windows

The majority of cars contain windows made of laminated safety sheet glass. Windows in 300 cars owned by one transit property consist of an acrylic/glass "sandwich." An improved scratch-resistant polycarbonate material has been specified by that transit system for new cars.

2.2 LIGHT RAIL

2.2.1 P.C.C. Cars

2.2.1.1 Seats - The original upholstered seats in these cars consisted of plywood and coil springs, topped with a layer of cotton batting covered with vinyl. In later years, some of these seat cushions were replaced with polyurethane. About 50 cars operated by one property are equipped with molded fiberglass seats.

2.2.1.2 Interior Liners - Ceiling and wall materials used include melamine-faced masonite, stainless steel, and aluminum.

2.2.1.3 Floor and Floor Covering - The flooring consists of a plywood panel. Rubber tiles are used for the floor covering.

2.2.1.4 Windows - With the exception of 200 cars equipped with polycarbonate windows, the windows in the majority of vehicles consist of laminated safety sheet glass.

2.2.2 Light Rail Vehicles (LRV)

2.2.2.1 Seats - The seats consist of a molded fiberglass shell containing thin neoprene cushions which are covered with fire retardant vinyl. The seat back is made of PVC/acrylic.

2.2.2.2 Interior Liners - The ceiling panels are made of PVC/acrylic. The window mask and wainscotting is a one-piece wall panel also made of PVC/acrylic.

2.2.2.3 Floors and Floor Coverings - The flooring panel consists of a plywood panel faced with a thin sheet of fiberglass. The floor covering material is sheet rubber.

2.2.2.4 Windows - The windows consist of laminated safety sheet glass.

3. IDENTIFICATION AND ANALYSIS OF COSTS

3.1 COST ESTIMATING METHODOLOGY

The cost analysis was performed by obtaining the weights or area of particular components and multiplying by the 1980 unit cost. After all costs in the analysis were found, the totals of Presently Used and Recommended materials were totalled and compared. In other words, cars which do and do not meet all recommendations are compared using calendar year, 1980 cost estimates.

Several independent factors can significantly influence the cost of a rail rapid transit car. These include inflation, size of the order, degree of standardization, size and weight of the car, and general business conditions.

Cost comparisons for some components were directly computed from the base costs and the individual weights or areas. For example, floor covering costs may be found using total pounds or total square footage and multiplying this number by the cost per pound or cost per square foot.

Cost estimates for other components were not derived as directly. While the base cost per pound was generally available, a large part of the delivered cost could be due to "value added" expenses, which contained variables such as the number and complexity of the molds required, the amount of waste produced, the size and thickness of the final product, and so on. Even components that appear to be similar (such as molded fiberglass for window masks and molded fiberglass for seats) may have different costs and densities due to the labor involved in forming the material and the quantities of the various additives used. Cost and weight data for certain interior components, e.g., lighting diffusers, thermal insulation, window and door seals, etc., could not be obtained. Often two or three estimates of the cost or the weight of a component produced conflicting data. In these cases, an average cost or weight was used (it should be noted that the price given for a particular component could vary by over

100 percent; for example, seat costs ranged from \$115 to \$243 for the same style seat). The total costs of the rail transit cars used in this analysis were derived from bid quotes, car builders and transit authorities. These estimates were then adjusted via the weighted average method (see below) to produce the cost of the "weighted fleet car."

Different rail transit properties specify different component materials, and choices also exist regarding future materials. Also, rail transit cars are quite variable in their specifications. For these reasons, three methods of analysis were used.

3.1.1 Weighted Fleet Car Method

To ascertain the average rise in cost of a rapid rail transit car, information on a number of cars was pooled to produce a "weighted fleet car." No car in use today is exactly like the "weighted fleet car," but this concept is useful as a quantitative tool when predicting the percent increase in costs across the entire nation. Three common types of rapid rail transit cars (ordered by three properties) totalling 2156 cars, were used in this process. They were chosen because they comprise a large portion of the existing fleet, and because good cost/weight information was available. Car type 1 comprises 70 percent of this total, while car types 2 and 3 represent 16 percent and 14 percent, respectively.

Essentially, a "weighted average" means that if 80 percent of the cars are of a particular type, this model will contribute 80 percent of the information to be used in the average car. The following examples will illustrate.

Assume two types of cars, Q and V. Q has 50 square feet of floor covering while V has 80 square feet. There are 38 Q cars and 12 V cars. To compute the weighted average the following operations were performed:

1. Total cars: 38 + 12 = 50 cars
2. Percent of each car: Q = 38/50 or 76% V= 12/50 or 24%

3. Weighted Average: 76% x 50 square feet = 38 square feet

24% x 80 square feet = 19.2 square feet

Composite total = 57.2 square feet.

The same result is achieved if each variable is multiplied by the number of cars of its type, the results are added and divided by the total number of cars:

1. 38 Q cars x 50 square feet = 1900 square feet
   12 V cars x 80 square feet = 960 square feet

2. 2860 square feet/50 cars = 57.2 square feet.

It is important to note that the composite total is not 65 square feet, which would be the average if only one Q and one V car were used.

In situations where different materials were used, the weighted method could be easily applied to the final cost of each component, producing the weighted cost.

3.1.2 The Worst/Best Case Method

The "worst/best" case analysis predicted the final cost of an aggregate-style RRT car using materials that differ in their resistance to fire.

The "worst" material was one that has been used within the last 10 to 20 years and does not meet the recommended criteria. Where more than one material was available, the less expensive material was chosen. For example, while seats could be filled with paper and thus be very inexpensive, this alternative was not realistic and therefore was not considered.

The "best" material chosen was one that met the recommended criteria and is or could be used in today's cars. The most expensive material within each category was not chosen, as it was felt that this would make the analysis artificial and meaningless. Transit properties generally try to minimize costs; cost increases due to preferences for luxury, durability of aesthetics are not

due to the fire safety considerations. As an illustration, some transit properties prefer the molded fiberglass seats rather than neoprene-upholstered seats due to cost, durability, and resistance to vandalism.

The Recommended material was the same in the "worst/best" case and "weighted fleet car" analysis.

3.1.3 Individual Car Analysis Method

To determine the impact upon individual transit properties the materials in three urban rapid rail transit cars and one urban light rail transit car were compared to determine cost increases which could be attributed to the adoption of the recommendations. If more than one material was used for the same component in different car orders, the one found in the majority was used to simplify the analysis. If a material already in use meets the recommended criteria, it was considered satisfactory and used as a recommended material. It should be noted that component comparisons across cars are not valid, due to the different seating arrangements, lengths, widths, and designs.

3.2 COST ANALYSIS RESULTS

The results of the various analyses provide an estimate of the expected increase in cost in new cars due to adoption of the Recommended Fire Safety Practices. The "change" in cost was divided by the expected cost of a new transit car, and the percent increase calculated. Using this procedure, it was then possible to compare the various urban transit fleets with each other, the "weighted fleet car" analysis and the "worst/best" case. Due to the variability inherent in the four urban rail transit vehicle designs (individual car analysis), the majority, but not all, of the material alternatives that meet the recommended criteria have been included. Quantity and unit cost figures have been modified to protect proprietary information.

3.2.1 Weighted Fleet Car

The results of the "weighted fleet car" analysis are found in Table B-1. The cost figures used were derived from the individual transit car analysis (See section 3.1.3 of Appendix B.) The total cost of materials that are used in transit cars was $14,861 as compared to the Recommended materials cost of $17,794. The difference of $2933 caused an increase in cost of approximately .43 percent when compared with the weighted expected cost of a new car.

3.2.2 The Worst/Best Case

The results of the "worst/best" analysis are found in Table B-2. The total cost of materials used in the "worst" case was $15,747 as compared to the "best" case cost of $17,794. (The Recommended costs are the same in Tables B-1 and B-2.) The $2047 difference could cause a new car to increase in cost by .30 percent.

It should be noted that the "worst/best" increase of .30 percent was less expensive than the .43 percent increase found in the "weighted fleet car" case. This was due to the higher cost of polyurethane seats. If the "weighted" cost of seats ($10,872 as compared to $13,300) derived from Table B-1, is substituted, the difference in cost amounted to $4475, yielding an increase of .65 percent.

3.2.3 Individual Car Analysis

The results of the individual transit car analyses are shown in Tables B-3, B-4, B-5 and B-6. Transit Authority (TA) 1, which owns a large segment of the cars in operation in the U.S. today (and is expected to order a large number of new cars in the next 10 years), currently utilizes many materials which meet the majority of the recommended criteria. Hence, the expected increase in cost (shown in Table B-3) was quite small (.08 percent), due only to the use of fire retardant rubber flooring and molded fiberglass window masks which meet the fire and smoke emission

TABLE B-1. COST ANALYSIS - WEIGHTED FLEET CAR

Component	Car Type	Material	Cost	Weighted %	Total Cost Presently Used	Total Cost Recom-mended
Floor	1	2SGS PLM	1475	.70	$1033	
	2	PLW&PLM	763	.16	122	
	3	2SA PLM	1875	.14	263	
Total					1418	
		2SA PLM	see "Worst-Best" Case			$1498
Floor Cover	1	Rubber	665	.70	466	
	2	Rubber	542	.16	87	
	3	Wool	1050	.14	147	
Total					700	
		Rubber - FR	see "Worst-Best" Case			1210
Ceiling Liner	1*	–	–	–	-	
	2	Mel	420	.16	67	
	3	PVC/A	2828	.14	396	
Total					463	
		PVC/B	see "Worst-Best" Case			1045
Window Mask	1	Mld Fbrgls	720	.70	503	
	2	PVC A	455	.16	73	
	3	PVC B	536	.14	75	
Total					652	
		Mld Fbrgls	see "Worst-Best" Case			825
Wall Liner	1	Mel PLM	320	.70	224	
	2*	–	–	–	-	
	3	PVCA	3413	.14	478	
Total					702	
		Mel PLM	see "Worst-Best" Case			560
Other	1*	–	–	–	-	
	2	Mel PLM	88	.16	14	
	3	Mel PLM	288	.14	40	
Total					54	
		Mel PLM	see "Worst-Best" Case			56
Seats	1	Mld Fbrgls	12,600	.70	8820	
	2	Poly Ur	9,500	.16	1520	
	3	PVC A/Neop	3,084	.14	432	
Total					10,872	
		Mld Fbrgls	see "Worst-Best" Case			12,600
TOTAL COST OF MATERIALS					$14,861	$17,794
INCREASED COST					$ 2933	

Increased Cost / Weighted Car Price = $ 2933 / $685,000 = .43 percent

*Components used are not flammable and not applicable to the analysis.

TABLE B-1. ABBREVIATIONS*

1 SA PLM	One-sided aluminum plymetal
2 SA PLM	Two-sided aluminum plymetal
2 SSA PLM	One-sided stainless steel + one-sided aluminum plymetal
2 SGS PLM	Two-sided galvanized steel plymetal
2 SSS PLM	Two-sided stainless steel plymetal
LRV	Light Rail Vehicle
Mel	Melamine
Mel PLM (PLW)	Melamine plymetal (plywood)
Mld Fbrgls	Molded fiberglass, fire retardant
Mld Fbrgls-FSR	Molded fiberglass, fire and smoke retardant
Mld Fbrgls-I	Molded fiberglass with inserts
Neop	Neoprene
Neop - FSR	Neoprene, fire and smoke retardant
PLM	Plymetal
PLW	Plywood
Poly UR	Polyurethane
PVC A	Polyvinyl chloride/acrylic, type A
PVC B	Polyvinyl chloride/acrylic, type B
Rubber - FR	Floor sheet rubber-fire retardant
TA 1	Transit Authority 1
TA 2	Transit Authority 2
TA 3	Transit Authority 3

*These abbreviations are used in all tables.

TABLE B-2. COST ANALYSIS - THE WORST/BEST CASE

Component	Material	Quantity	Unit Cost	Total Cost-Presently Used	Total Cost-Recommended
Floor	Plywood	681 ft^2	$1.15	$783	
	2SA PLM	681 ft^2	2.20		$ 1498
Floor Cover	Vinyl Tile	681 ft^2	.55	375	
	Rubber-FR	75.6 yd^2	16.00		1210
Ceiling Liner	PVC A	160 lbs	3.25	520	
	PVC B	190 lbs	5.50		1045
Window Masks	PVC A	195 lbs	3.25	634	
	Mld Fbrgls	220 lbs	3.75		825
Wall Liners	PVC A	40 lbs	3.25	130	
	Mel PLM	350 lbs	1.60		560
Other	Poly Ur	5 lbs	1.00	5	
	Mel PLM	35 lbs	1.60		56
Seats	Poly Ur	70 seats	190.00	13,300	
	Mld Fbrgls	70 seats	180.00		$12,600
TOTAL COST OF MATERIALS				$15,747	$17,794
INCREASED COST				2,047	

Increased Cost/Weighted Car Price = $ 2047/$685,000 = .30%

Increase due to subtitution of Weighted Fleet Car Cost of seats:

Seats	Weighted	see "weighted" figure*	10,872	
	Mld Fbrgls	70 seats 180.00		12,600
TOTAL COST OF MATERIALS			$13,319	$17,794
INCREASED COST			$ 4475	

Increased Cost/Weighted Car Price = $ 4475/$685,000 = .65%

*Table B-1.

TABLE B-3. COST ANALYSIS - TA 1

Component	Material	Quantity	Unit Cost	Total Cost-Presently Used	Total Cost-Recommended
Floor	2SGS PLM	2950 lbs	$.50	$1475	
	2SGS PLM	2950 lbs	.50		$ 1475
Floor Cover	Rubber	700 lbs	.95	665	
	Rubber-FR	700 lbs	1.50		1050
Ceiling	Aluminum				
	Aluminum				
Window Masks	Mld Fbrgls	240 lbs	3.00	720	
	Mld Fbrgls-FSR	240 lbs	3.75		900
Wall Liners	Mel PLW	200 lbs	1.80	360	
	Mel PLW	200 lbs	1.80		360
Seats	Mld Fbrgls	70 seats	180.00	12,600	
	Mld Fbrgls	70 seats	180.00		12,600
TOTAL COST OF MATERIALS				$15,820	$16,385
INCREASE IN COST				$ 565	

Increased Cost/TA 1 / Car Price $565/$725,000 = .08 percent

TABLE B-4. COST ANALYSIS - TA 2

Component	Material	Quantity	Unit Cost	Total Cost-Presently Used	Total Cost-Recommended
Floor	PLW + 2SSS PLM	276 ft^2 + 137 ft^2	$1.15 + $3.25	$ 763	
	2SSA PLM	414 ft^2	2.70		$ 1118
Floor Cover	Rubber	570 lbs	.95	542	
	Rubber-FR	570 lbs	1.50		855
Ceiling Liner	1/8" Mel	280 lbs	1.50	420	
	1/8" Mel	280 lbs	1.50		420
Window Masks	PVC A	140 lbs	3.25	455	
	Mld Fbrgls	24 masks	68.75		1650
Other	Mel PLM	55 lbs	1.60	88	
	Mel PLM	55 lbs	1.60		88
Seats	Poly Ur	50 seats	190.00	9500	
	Mld Fbrgls-I	50 seats	190.00		9500
TOTAL COST OF MATERIALS				$11,798	$13,631
INCREASE IN COST				1833	

$$\text{Increased Cost}/\frac{\text{TA 2}}{\text{Car Price}} \quad \$\,1833/\$450{,}000 = .41 \text{ percent}$$

TABLE B-5. COST ANALYSIS - TA 3

Component	Material	Quantity	Unit Cost	Total Cost-Presently Used	Total Cost-Recommended
Floor	2SA PLM	2500 lbs	$ .75	$ 1875	
	2SA PLM*	2500 lbs	.75		$ 1875
Floor Cover	Wool	75 yd^2	14.00	1050	
	Wool	75 yd^2	14.00		1050
Ceiling Liner	PVC A	870 lbs	3.25	2828	
	PVC B	1000 lbs	5.50		5500
Window Masks	PVC A	165 lbs	3.25	536	
	PVC B	190 lbs	5.50		1045
Wall Liner	PVC A	1050 lbs	3.25	3413	
	PVC B	1200 lbs	5.50		6600
Other	Mel PLM	180 lbs	1.60	288	
	Mel PLM	180 lbs	1.60		288
Seat Backs	PVC A	240 lbs	3.25	780	
	PVC B	275 lbs	5.50		1513
Seat Cushions	Neop.	960 lbs	2.40	2304	
	Neop. FSR	960 lbs	2.55		2448
TOTAL COST OF MATERIALS				$ 13,074	$ 20,319
INCREASE IN COST				$ $ 7245	

Increased Cost / TA 3 Car Price $\quad$ $7245 / $740,000 = .98 percent

* TA 3 is ordering 2SSS PLM in the new cars, for additional structural support. A cost increase would accrue due to this substitution.

TABLE B-6. COST ANALYSIS - LRV

Component	Material	Quantity	Unit Cost	Total Cost-Presently Used	Total Cost-Recommended
Floor	Plywood	518 ft^2	$1.15	$ 596	
	1 SA PLM	518 ft^2	1.70		$ 881
Floor Cover	Rubber	900 lbs	.95	855	
	Rubber-FR	900 lbs	1.50		1350
Wall and Ceiling Liners, Window Masks & Seat Backs	PVC A	1450 lbs	3.25	4713	
	PVC B	1660 lbs	5.50		9130
Seat Cushions	Neop	50 seats	6.50	325	
	Neop	50 seats	6.50		325
Seat Covers	Vinyl-FR	35 lin yds	4.50	158	
	Vinyl-FSR	35 lin yds	4.50		158
Windscreen Partitions	Mel PLM	400 lbs	1.60	640	
	Mel PLM	400 lbs	1.60		640
TOTAL COST OF MATERIALS				$ 7287	$12,484
INCREASED COST				$ 5197	

Increased Cost / LRV Car Price = $5197 / $750,000 = .69 percent

of the recommended criteria.

TA 2, (Table B-4) shows an increase of .41 percent. However, cost increases in this case were primarily due to change in transit property design requirements rather than fire safety considerations. This is particularly true in the substitution of window masks made of molded fiberglass instead of PVC/acrylic.

The increase in cost for TA 3 (Table B-5) was .98 percent, the highest increase found. TA 3 cars contain a high percentage of a PVC/acrylic which does not meet the recommended criteria. The comparable Recommended PVC/acrylic, which is more expensive, accounts for most of the expected price increase.

The standard light rail vehicle (LRV) (Table B-6) cost increase was approximately .69 percent or $5197. The factors that account for this increase included the change in floor and floor covering material and the more expensive PCV/acrylic.

3.3 SENSITIVITY OF THE COST ANALYSIS

The cost increase due to the adoption of the Recommended Fire Safety Practices varies between .08 percent and .98 percent. As stated previously, the analysis rests upon material cost estimates and other data that were not readily available. Considerable efforts were made to obtain cost estimates for materials from various companies which actually produce many of the components. It is therefore expected that the analysis represents a realistic assessment of the projected cost increases.

Another consideration is the relationship between interior component costs and the final cost of the transit vehicle. Using the weights of various components of an MBTA Light Rail Vehicle (LRV), Charles P. Elms of N.D. Lea & Associates, [5] recently calculated that the cost of interior components (seats, interior linings, etc.) would comprise about 3 percent of the final vehicle cost.

Cost increases resulting from compliance with the recommendations would thus have a minimal effect on the final cost of the

individual transit vehicle. To illustrate, if the cost of the basic material ingredients used by the supplier had to be doubled in order to meet the recommended criteria, then the cost to the car builder for these interior materials would increase by 33 percent. On the other hand, if both labor and ingredient cost doubled, then the cost might increase by a factor of two. (This assumes that the cost of materials is one-third ingredients and two-thirds labor, overhead, profit, etc.) On this basis, the increase in the final total cost of the vehicle might amount to between 1 percent and 3 percent. These figures correlate closely with those obtained in this study.

It is still relevant, however, to question the sensitivity of the analysis. There are various ways to approach this problem, including changing the costs of the components, changing the final cost of the vehicle, comparing the expected cost increase against some standard, and altering the increased cost due to the recommendations.

Based on a 30-year replacement cycle, it is expected that (10,800/30) or 360 cars per year must be replaced (3.3 percent of the national fleet). Since 1968, 4259 new cars have been delivered or ordered, which represents 39 percent of the total current rail transit fleet. A close correlation exists between these two numbers based upon an 11-year time span. The "weighted fleet car" cost increase of $2933 multiplied by $1,055,880. This is well below the expected cost that will be incurred by transit vehicle fires in one year.

Essentially, the cost analysis is not subject to minor (or even major) changes in costs of materials or numbers of cars ordered. Regionwide, however, an increase of perhaps $20,000 per car for 400 cars may be of some concern (total: $8 million out of a final cost of $274,000,000). However, this is still below a 3 percent increase in costs.

APPENDIX B
REFERENCES

1. Roster of North American Rapid Transit Cars, 1945-76, UMTA-DC-06-0121-77-1, American Public Transit Association (January 1977).

2. Vehicle bid specifications library maintained by Transit Systems Branch, Urban Systems Division TSC.

3. Conversations with Charles P. Elms, N.D. Lea & Associates and Ray Cavenaugh, L.T. Klauder & Associates.

4. Material and weight data received from William Walker, Pullman Standard and William Dickart, Budd Company.

5. Conversation with Charles P. Elms, N.D. Lea & Associates, January 25, 1980.